International Journal of Mechanical and Production Engineering Research and Development (IJMPERD)
ISSN (P): 2249-6890; ISSN (E): 2249-8001
Vol. 8, Issue 1, Feb 2018, 635-642

FABRICATION OF ALUMINIUM 6061- SiC-Al_2O_3 MMC AND HMMC BY STRIR CASTING TECHNIQUE AND COMPARING THE MECHANICAL PROPERTIES

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ABSTRACT

Aluminum alloys are extensively used in aerospace and automobile industries owing to their low density and good mechanical properties, superior corrosion resistance and wear, low thermal coefficient of expansion as compared to usual metals and alloys. From the collected literature, it is found that, metal matrix composites are considered as prospective materials and hence it is mainly used to replace usual materials in aerospace and automotive applications. The advantage of MMCs is that, it can have light weight as well as at the same time, it can be hardened and strengthened by reinforcing it with hard ceramics reinforcements like Sic, Al_2O_3 etc. In this work, aluminium is selected as matrix due to its low weight, good weldability and good mechanical properties. The aim of this project is to fabricate material for the applications of engine piston, bumpers and test the mechanical properties such as hardness, Impact strength and wear resistance. In this work, the stir casting method was used to fabricate the composite which is a liquid state process. After that various mechanical testing is conducted and comparison is carried out.

KEYWORDS: MMCs, Stir Casting, Aluminium 6061, Silicon Carbide, Aluminium Oxide & HMMC

Received: Nov 30, 2017**; Accepted:** Dec 21, 2017**; Published:** Jan 13, 2018**; Paper Id.:** IJMPERDFEB201870

Original Article

INTRODUCTION

Composite material is a material made from two or more ingredient materials with significantly different physical or chemical properties that, when combined, produce a material with character different from the individual components. The individual components stay separate and distinct inside the finished structure. The new material may be wonderful for numerous reasons: typical examples include materials which are stronger, lighter, or less expensive when compared to traditional materials.

Aluminium matrix composites are emerging as advance engineering materials due to its high specific strength and stiffness, good wear resistance and high temperature properties. Aluminium alloys are an important engineering material for mechanical and wear applications. Because it is have low density, improved machinability, high specific strength, superior wear resistance, and low thermal conductivity. Aluminium alloys are typically used in automobile, aerospace, and mineral processing industries. Inclusion of hard ceramic part to a relatively soft matrix alloy, commonly aluminium, improves the strength, creep performance, and wear resistance of the alloy [2, 3]. The aluminium matrix can be strengthened by reinforcing with hard ceramic particles like SiC, Al2O3,etc. The mechanical properties such as flexural strength, tensile strength and hardness of the aluminium alloys are amplified by addition of alumina Al_2O_3, boron carbide B_4C and Sic [4]. Presence of hard ceramic particles like sic and Al_2O_3

increases microhardness value [5]. Metal matrix reinforced with more than one reinforcement with varying volume fraction (3 to 12 wt. %) has striking effect on wear rate. By increasing the volume fraction of reinforcements the wear rate and coefficient of friction decreases [6].

In this assignment, aluminium 6061 alloy is selected as one of fundamental parts, which has good mechanical properties and exhibits good weldability. The reinforcements are tested for hardness, impact, and wear. These materials are applied in automobile industries and aerospace industries. Current engineering applications require materials that are stronger, lighter and less expensive. A fine example is the current interest in the development of materials that have good strength to weight ratio suitable for automobile applications where fuel economy with better engine performance is becoming more critical. In-service performance demands for many modern engineering systems require materials with broad spectrum of properties, which are quite difficult to meet using monolithic material systems Metal matrix composites (MMCs) have been noted to offer such customized property combinations required in a ample range of engineering applications. Some of these property combinations include high specific strength, low coefficient thermal expansion and high thermal resistance, good damping capacities, superior wear resistance, high specific stiffness and satisfactory levels of corrosion resistance. It is identified that Al6061 is better material for metal matrix owing to its better formability characteristics and high temperature properties [1].

Numerous techniques were developed for fabricating particulate reinforced MMCs, such as powder metallurgy [7], in situ [8], and squeeze casting [9]. From all the above three methods, stir casting technique is the simplest and the most economical process for fabricating particulate reinforced MMCs [11].

In this work, an attempt has been made to fabricate metal matrix composites with SiC (3%wt and 6%wt), Al_2O_3 (3% and 6%) and HMMC (3% SiC and 3% Al_2O_3). Various mechanical properties of these composites were examined and compared.

EXPERIMENTAL WORK

Methodology

- The following procedures were employed to carry out this work. It has been displayed as flow chart below.

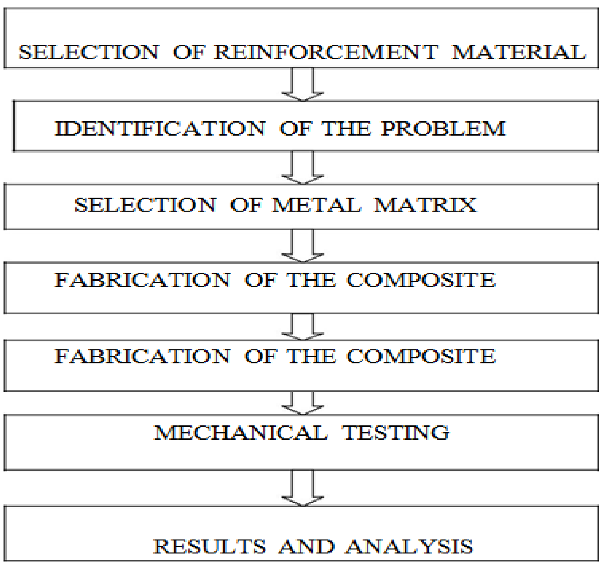

Figure 1: Flow Chart of Methodology

Material Selection

In this investigation, Al 6061 grade alloy is selected as matrix. The reason for the selection of this grade alloy is that, it contains magnesium and silicon as its major alloying elements which improves mechanical properties and exhibits good weldability. The approximate composition of Al 6061 is given in the table below:

Table 1: Composition of Al6061 Alloy

Element	% Wt.
Mg	1.08
Si	0.63
Mn	0.52
Cu	0.32
Fe	0.17
Ti	0.02
V	0.01
Al	Remaining

The two reinforcements i.e., SiC and Al_2O_3 are used at 3% and 6% by weight of aluminimum. In addition to this a HMMC is fabricated by 3% SiC and 3% Al_2O_3 by weight.

Fabrication of Composites

Stir casting process is mostly used for manufacturing of particulate reinforced metal matrix composites. The method of stir casting, operating parameters and processing and preparation of AMC material using Al 6061 as matrix alloy and reinforcements Silicon Carbide and alumina have been fabricated by varying weight fractions. Stir casting generally involves extended liquid reinforcement contact, which can cause considerable interface reaction. In the present study, the effect of Silicon Carbide and alumina on stir cast Aluminium Metal Matrix Composites has been discussed. 3 Kg of Al 6061 alloy pieces in the Muffler furnace is heated and allow the same to melt at 780°C and care has been taken to achieve complete melting.

Figure 2: Muffler Furnace

The alloy pieces are kept in the crucible and preheat the mould at the required temperature 750°C - 800°C. Preheat the reinforcements like Silicon Carbide and alumina that are to be added, at the same temperature range.

Figure 3: Addition of Preheated Salts to the Muffler Furnace

Slag has been removed using scum powder to avoid poor quality casting and maintained at the same temperature for about 20 minutes to remove the moisture casting. Approximately 5% weight of solid dry hexachloro-ethane tablets or degassing tablets has been used to degas the molten metal at temperature 780°C. Stirring process of the molten metal to produce vortex by way of stir casting process and the temperature of molten metal has been maintained around 750°C. The stirring of the mixture has been carried out to ensure uniform distribution of reinforcements in the matrix material. Continuous stirring has been accomplished at the range 400 – 750 rpm to a time of about 30 minutes. After smooth solidification process, preheat the mould to avoid shrinkage of casting metal for about 3 hours to complete the process.

Figure 4: Casted Samples

The cast composites are further extruded to decrease porosity, improvement of microstructure and normalize the distribution of the reinforcements. The prominent concern associated with the stir casting process is the segregation of reinforcing particles which is caused by the surfacing or settling of the reinforcement particles during the melting and casting processes. The final distribution of the particles in the solid depends on material properties and process parameters such as wetting condition of the particles, strength of mixing, relative density and the rate of solidification. The distribution of the particles in the molten matrix depends on the geometry of the mechanical stirrer, stirring parameters, positioning of the mechanical stirrer, melting temperature and the characteristics of the particles.

In the research work, Al 6061 is selected as the matrix alloy and the reinforcements are Silicon Carbide and Aluminium oxide.

Table 2: Percentage Compositions of the Samples

S. No	Composition
1	Al + 3% SiC by Wt.
2	Al + 6% SiC by Wt.
3	Al + 3% Al_2O_3 by Wt.
4	Al + 6% Al_2O_3 by Wt.
5	Al + 3% SiC + 3% Al_2O_3 by Wt.

TESTING OF MATERIALS

After the castings are machined, then it is tested for hardness, impact and wear. The hardness test is carried out using the Micro Vickers testing machine and impact test is carried out using Impact testing machine and the wear test is carried out using the pin on disc apparatus.

Hardness Test

Hardness is a measure of how resistant solid matter to various kinds of permanent shape change when a compressive force is applied. Hardness is measured at different locations. The micro hardness of the samples is measured using Micro Vickers testing method at 0.5kg load.

Table 3: Tabulation of Hardness to Different Compositions

S. No	Composition	R1 (KHN)	R2 (KHN)	R3 (KHN)	Avg. (KHN)
1	3% Sic	82.1	83	84.3	83.13
2	6% Sic	87.6	88.4	90.3	88.76
3	3% Al_2O_3	72	72.9	72.2	72.36
4	6% Al_2O_3	63.7	64.6	68.8	63.7
5	3% Sic + 3% Al_2O_3	68.8	82	84.7	78.5

It has been observed from the table 3 that micro hardness of Aluminium matrix reinforced with Silicon Carbide is more than the aluminium reinforced with Alumina for same weight percentage. It can be seen from the table that the hardness value of 6% of SiC composites is more when compared to 3 % of SiC composites. So it is concluded that as silicon carbide content in aluminium metal matrix, hardness of the aluminium metal matrix increases.

Impact Test

Impact tests are used to determine the toughness of the material. A material's toughness is a factor of its ability to absorb energy during plastic deformation. Izod impact testing method is an ASTM standard method of determining the impact resistance of materials.

Table 4: Tabulation of Impact to Different Compositions

S. No.	Composition	Impact In Joules
1	3% Sic	2.2
2	6% Sic	3.2
3	3% Al_2O_3	8.3
4	6% Al_2O_3	13.1
5	3% Sic + 3% Al_2O_3	8

It has been observed from the Table 4, that impact value of aluminium reinforced with the alumina is more than the aluminium reinforced with the alumina for same weight percentage. It can be seen from the table that impact value of 6% of Alumina is more when compared to 3% of Alumina. So it is concluded that as alumina content in aluminium metal matrix increases, impact value of aluminium metal matrix composites (i.e., the specimen can withstand more shock load.)

Figure 5: Specimen after Impact Test

Wear Test

Wear is a process of elimination of material from one or both of two solid surfaces in solid state contact. As the wear is a surface removal phenomenon and occurs mostly at outer surfaces, it is more appropriate and economical to make surface modification of existing alloys than using the wear resistant alloys. Wear test was performed using Pin on disc apparatus.

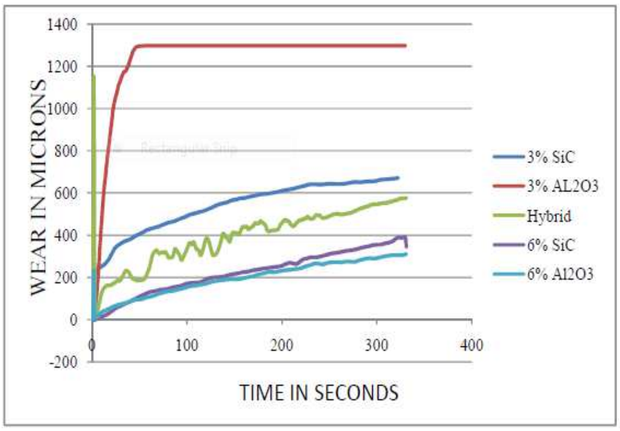

Figure 6: Time Vs Wear

The Figure 6 is used to find the wear in microns with respect to the time. From this graph, it is found that 6% Al_2O_3 has more wear resistance than all other composites. And also found that the wear resistance of aluminium reinforced with the alumina increases with the increase in alumina content.

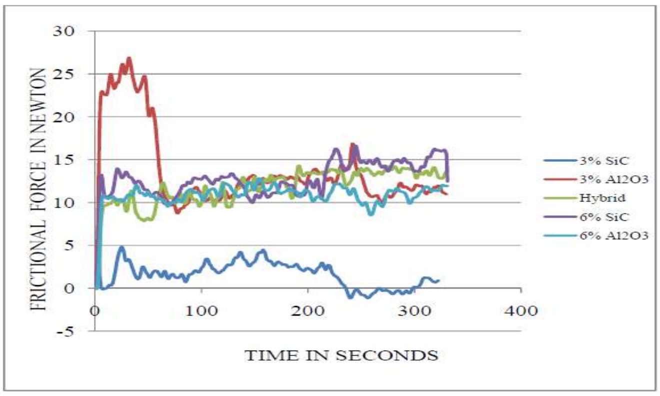

Figure 7: Time Vs Frictional Force

Figure 8: Pin Used for Wear Testing

From the Figure. 7, it is inferred that the negative value in 6% Al_2O_3 specimen shows that material is more wear resistant than other materials, as this specimen removes the material from the disc.

CONCLUSIONS

From this research wok, the following conclusions are derived:

- When 3% and 6% of silicon carbide is compared with 3% and 6% of aluminium oxide in aluminium matrix the hardness value is high in silicon carbide composite; and impact value is high in the aluminium oxide composite.
- As the amount of silicon carbide increases in the composite, hardness value increases.
- Similarly as aluminium oxide content increases in the composites, the impact value increases (i.e., the specimen can withstand more shock load).
- In case of the hybrid composite (i.e., 3% of aluminium oxide and 3% silicon carbide in the aluminium matrix), it has moderate properties (i.e., it shows both properties in a moderate manner).
- When 3% and 6% of silicon carbide is compared with 3% and 6% of aluminium oxide in aluminium matrix, it is found that 6% Al2O3 has more wear resistance than all other composites. And also found that the wear resistance of aluminium reinforced with the alumina increases, with the increase in alumina content.
- 6% Al_2O_3 material can be used in bike cylinders as it is wear resistant and can withstand more shock loads.

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